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ACID RAIN STUDIES - EMISSIONS INVENTORY: A REVIEW

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ABSTRACT

Current and historical anthropogenic emissions of sulfur dioxide, nitrogen oxides and hydrocarbons in North America have been compiled. The summarized results have been studied for historical, geographical and seasonal trends with emphasis on the eastern portion of the continent. Historically, both US and Canadian acid gas emissions have increased since 1940 to a maximum in the 1970's in the US and a similar peak around 1970 in Canada. The most recent emissions compilation (1980) indicated that the eastern US is the largest emitter of acidic gases in Eastern North America. Sulfur dioxide emissions in the US have been spreading towards the southern and western States in accordance with the spatial shift in coal consumption which occurred during the time periods examined. Emissions from Ontario Hydro generating stations have been compared to provincial, national and North American emissions. Ontario emits approximately one-half of the eastern Canadian acidic gases and hydrocarbons. Ontario Hydro emits less than one-quarter of the Ontario sulfur dioxide and less than one-fifth of the Ontario nitrogen oxides. The estimated percentage contribution of Ontario Hydro generating station emissions to Eastern North American emissions was 1.7% for sulfur dioxide and 0.8% for nitrogen oxides.

1.0 INTRODUCTION

The Thermal Generation Division requested that a number of acid rain studies be carried out by the Atmospheric Research Section in 1982. These included (a) a review of the latest information on acidic gas and hydrocarbon emissions, (b) analysis of the atmospheric

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conditions associated with winter acidic deposition episodes in 1978-79 and 1980-81 and (c) the application of the CEGB long range transport model to Ontario Hydro and Eastern North American emissions. This report describes the work done on acid gas and hydrocarbon emissions.

In the late 1970's acid rain became a public issue in North America with governments identifying it as one of the most serious environmental problems facing mankind/1/. The emissions of sulfur and nitrogen oxides have been implicated in the formation of acid rain with suspected ecological effects far from the point of emission/2/. Emission controls have been called for to reduce the threat of acid rain.

Acid rain and acid precipitation have become the generic terms now used to describe the deposition of acidic substances by both wet and dry processes/3/. Precipitation has traditionally been considered acidic when it has a pH value of less than 5.6, the theoretical pH value of a carbon dioxide saturated water solution. There is some recent evidence to suggest that naturally occurring precipitation acidity may be around pH 5 instead of pH 5.6/20/.

The acidity of wet deposition is dominated by sulfuric and nitric acids. Dry acidic deposition includes sulfur dioxide (SO_2), nitrogen oxides (NO_X), sulfate and nitrate aerosols and nitric acid. There are both natural and man-made sources of these substances. Man-made emissions generally occur as sulfur dioxide and nitric oxide (NO)/3/. The nitric oxide is converted, through reactions with oxygen and ambient ozone, to nitrogen dioxide (NO_2) within a matter of a few hours of residence in the atmosphere/1/. Nitric oxide plus nitrogen dioxide are collectively termed NO_X.

The major precursors of acid rain are sulfur dioxide and nitrogen oxides. Through atmospheric reactions, SO_2 and NO_X are converted to sulfur and nitrogen acids. The three main pathways responsible for the chemical conversions are photochemical, liquid phase and surface catalytic oxidation/1/. The latter is thought to be insignificant due to insufficient availability of atmospheric particulate mass or surface area. Liquid phase oxidation is not very well understood, and the relative importance of photochemical and liquid phase oxidation is still an area of debate today. The photochemical oxidation process,however, is relatively well known. Sulfur dioxide and nitrogen oxides are not photooxidized directly but rather through the action of active free radicals produced from photochemically active mixtures of hydrocarbons (HC) and nitrogen oxides. Thus, emissions of sulfur dioxide, nitrogen oxides and hydrocarbons, as well as the ratio of nitrogen oxides to hydrocarbon emissions (NO_X/HC), are of interest in studies of the photochemical activity of the atmosphere and the formation of acid rain.

Much of Eastern North America is being affected by precipitation with a mean pH between 4.1 and 4.5/4/. This report summarizes current and historical anthropogenic emissions of the pollutants involved in acid rain formation in North America with emphasis on the eastern portion of the continent. Natural sources will not be included in the discussion since in Eastern North America these emissions are minimal in comparison to the man-made emissions. On a global scale, however, natural emissions are considered to be dominant/4/. In Eastern North America, biogenic sulfur emissions are only 5% of the anthropogenic emissions. Man-made sources of nitrogen tend to be locally concentrated at 10 to 100 times the natural values.

The emissions summary compiled in this project has been studied for historical, geographical and seasonal trends. The possible influence of the ratio of nitrogen oxides to hydrocarbon emissions on the photochemical activity of the atmosphere, over the years, has been investigated. Emissions from Ontario Hydro generating stations have been compared to provincial, national and North American emissions.

Data records on emissions have only been maintained since the early 1970's. Historical emissions have been estimated by applying other available information such as fuel-use data and the sulfur content of fuel/5/. The accuracy of emission estimates is, at best, ±15% when considered on a nationwide, annual basis/6/. The utility sector estimates are probably within ±25% for the post-1965 years/5/. An analysis made of Canada's 1976 inventory indicated that the overall SO_2 inventory for Canada is accurate to within ±30% at the 75% confidence level/5/. The most recent listing of emissions (1980) included a probable error which was calculated for all States and Provinces/7/.

2.0 APPROACH

Literature concerning acid rain was used as the major source of emission data. The best available information on man-made emissions was obtained through personal contacts and from pre-published draft reports. Up-to-date, Ontario Hydro emissions data were obtained from the Thermal Generation Division of Ontario Hydro. With new data continually emerging, an arbitrary cutoff date for reviewing new information was set to allow for the completion of this report.

3.0 RESULTS

3.1 Historical Trends in Acid Gas Emissions in North America

United States acid gas emissions, dating back to 1940, have been summarized in the US-Canada Memorandum of Intent (MOI) on Transboundary Air Pollution, 3B-Final Report, June, 1982/5/ and are presented in Table I. Figure 1 depicts a bar graph of the US emissions at ten-year intervals, from 1940 to 1970, and for 1975 as extracted from Ontario Hydro Report No CTS-07165-1/4/. The 1980 emission values included in Table I were agreed upon by the MOI working groups/1/ and these 1980 results will be reported in the upcoming Phase III report/8/. In December 1978, a report compiled by the US Environmental Protection Agency (EPA)/9/ summarized US releases for the years 1970 to 1977 (see Table II). These values differed slightly (±3%) from the MOI values. A draft report written by United Technology and Science Incorporated/10/ gave SO_2 and NO_x emissions for 1970 to 1975 (see Table III) that were up to 15% larger than the emissions reported in Tables I and II.

Pre-1970 historical emission trends for Canada are unavailable/4,6, 11,12/. However, the MOI working group 3B/5/ was able to estimate SO_2 and NO_x releases for 1955 and 1965. These historical values,

along with emissions for the 1970's from Environment Canada/13,14,15,16/ and 1980 emission values for Canada that were agreed upon by the MOI working group/7,8/ are collectively shown in Table IV. This tabulation provides an indication of historical trends in emissions for Canada. Eastern Canadian emissions for the same time period, are collected in Table V. For Ontario, only releases for the 1970's were available, and these values are listed in Table VI.

3.2 Historical Trends in NO_x/HC Ratios

The ratio of nitrogen oxides to hydrocarbon emissions is of interest in studies of the photochemical activity of the atmosphere. Historical NO_x/HC ratios were calculated from the US emission data and are listed in Table VII. Figure 2 depicts the historical trend of the NO_x/HC ratio in the US. This ratio increased sharply in the US from 1960 to 1970 and continued to increase yearly in the 1970's. NO_x/HC ratios were determined for Canada, Eastern Canada and Ontario for the 1970's. These results are listed in Table VIII. In Canada, the ratio increased roughly 25% between 1970 and 1980.

3.3 Geographical Shift in Emissions

Sulfur emissions have been increasing in the southern and western portions of the US. Maps displaying the sulfur emission density due to coal combustion, since 1889, (Figure 3) illustrate this spread as do the maps depicting sulfur emissions from all sources for 1965, 1973 and 1985 (Figure 4)/17/. To better illustrate the geographical trend in emissions, eastern US States were grouped according to the EPA regions (see Figure 5). The total SO_2 emissions for each region are given in Table IX/5/. Sulfur dioxide emissions have decreased moderately (roughly 45%) in the northeastern States (Region I and II), while in the southeastern States (Region IV), the SO_2 emissions have increased dramatically (approximately 430%) between 1950 and 1978.

3.4 Current (1980) Emissions

The most recent acid gas and hydrocarbon emissions summary is for the year 1980. It was compiled by MOI Working Group 3B/7,8,23/. United States and Canadian emissions, along with emissions for the eastern portion of the continent (see Figure 6), have been compared to total releases for North America (Table X). Emissions for the eastern US were divided, such that the States adjacent to Ontario were considered separately with more distant States being grouped to form regions (see Figure 7). The releases for these States and regions are compiled in Table XI.

Eastern Canadian emissions were divided along the provincial boundaries with the exception of the Maritime Provinces which were considered collectively (Figure 8 and Table XII). The Provinces were further divided into subregions (Figure 8) with the emissions for each of the subregions being listed in Table XIII. Maps of the SO_2 and NO_x emission data, depicted by region, are shown in Figures 9 and 10.

Working Group 3B has calculated the precision of the 1980 sulfur dioxide and nitrogen oxides emission data for each State (Table XIV), each Province (Table XV) and for each of the Canadian subregions (Tables XVI and XVII).

3.5 Ontario Hydro Emissions

The most recent (1980) SO_2 and NO_x emission data for Ontario Hydro generating stations were obtained from Thermal Generation Division of Ontario Hydro/18/ and are presented in Table XVIII. The relative contribution, by Ontario Hydro, towards provincial, national and North American emissions was calculated and the values are presented in Table XIX. The Ontario Ministry of the Environment, Air Resources Branch/19/ ranked the top 50 coal-fired power plants from Ontario and 32 Eastern US States according to total SO_2 emissions for 1980 (Table XX). The coal-fired power plants were also ranked according to SO_2 emission cleanliness by using estimated values of the amount of SO_2 emitted per unit of energy produced, Table XXI. The relative positions of the Ontario Hydro generating stations (Lambton, Lakeview and Nanticoke) have been underlined in Tables XX and XXI.

3.6 Seasonal Trends in Emission

There was a scarcity of good seasonal emission data for eastern North America. What was available has been evaluated.

Seasonal variations in Canadian emissions of SO_2 and NO_x were obtained from the MOI, Working Group 3B, Final Report, June, 1982/5/ and are summarized in Table XXII. Sulfur dioxide emissions increased in the winter and were at a minimum in the summer. Nitrogen oxide emissions showed an increase in the summertime. Seasonal trends for the emissions data collected as part of the Sulfate Regional Experiment (SURE) are presented in Table XXIII/21/. The SURE area encompassed parts of southern Canada and all the States in the eastern half of the US as shown in Figure 11/22/. The SURE data showed a slight maximum in SO_2 emissions in the winter with no significant summertime minimum being observed. Nitrogen oxide emissions showed no significant seasonal trends, however, a large increase in hydrocarbon emissions was apparent for the winter months.

4.0 DISCUSSION

Acid gas emissions in the US have shown a moderate increase (approximately 20-40%) for SO_2, along with a dramatic increase (approximately 300%) for NO_x between 1940 and the mid-1970's. Hydrocarbon emissions increased nearly 75% from 1940 to 1970 and then decreased slightly (about 6%) in 1976. Emissions of all three pollutants showed an overall decrease between 1976 and 1980, with sulfur dioxide emissions being reduced approximately 10%, nitrogen oxide emissions decreasing about 15% and hydrocarbon emissions having the largest reduction, about 20%.

Sulfur dioxide emissions in Canada increased approximately 50% while eastern Canadian SO_2 releases increased moderately by about 35% between 1955 and 1970. Since 1970, both Canadian and eastern Canadian SO_2 emissions have decreased moderately (roughly 30%) while Ontario SO_2 emissions showed a larger decline of about 47%.

Nitrogen oxide releases increased by a factor of six in Canada, and by a factor of almost five in eastern Canada from 1955 to 1974. Canadian NO_x emissions showed a marginal decline of about 3% from 1974 to 1980, while NO_x emissions in eastern Canada stayed relatively constant. Nitrogen oxide emissions in Ontario were essentially constant from 1972 to 1980, except for a maximum in 1974, roughly 13% above the remaining years.

Hydrocarbon emissions in all three Canadian regions, fluctuated in the 1970's with an overall decrease of approximately 30 to 35% being observed between 1970 and 1980.

The nitrogen oxide to hydrocarbon emissions ratio in the US remained essentially constant between 1940 and 1960 and then a sharp rise of approximately 81% occurred between 1960 and 1970. A yearly increase in the NO_x/HC ratio was observed from 1970 to 1980 resulting in an overall increase of almost 25% in that decade. The ratios calculated from MOI data in Table I indicated a peak in 1975 which did not appear in the EPA data listed in Table II. Also, the ratios based on MOI data were up to 3% larger than those based on EPA data.

The NO_x/HC ratios in Canada, eastern Canada and Ontario increased by approximately 70%, 85% and 90% respectively from 1970 to 1972. The ratios fluctuated from 1972 to 1976 with an overall increase of between 5% and 20% for Canada, eastern Canada and Ontario. In 1980, the NO_x/HC ratio rose between 25 and 35% in the above three regions.

A southwesterly spread in sulfur emissions through the years has become apparent in the US. Coal combustion constituted the most significant sulfur source. The historical trend in sulfur emissions, therefore, closely reflected the coal consumption trends, Figure 3/17/. The spatial distribution of sulfur emissions has been spreading from the northeastern States towards the more central States of Kentucky, Tennessee, North and South Carolina, in accordance with the spatial shift in coal consumption.

Sulfur dioxide releases for eastern US States, grouped according to EPA regions, showed the same south and westward spread in emissions/5/. In the northeastern States (Regions I, II), SO_2 emissions have decreased by about 40-45% from 1950 to 1978, whereas SO_2 emissions in the southeastern States (Region IV) have increased by approximately 430%.

The US is the major emitter of the precursors of acid rain in North America. The US emitted 83% of the North American SO_2, 91% of the NO_x and 92% of the HC in 1980. A large portion (approximately 82%) of the SO_2 emissions, along with about 65% of the NO_x and HC emissions originated in the eastern US.

A regional study of the eastern US emissions, as depicted by Figure 5, indicated that the Illinois-Indiana region contributed the greatest amount of SO_2 emissions (3,154.8 kilotonnes per annum) and Ohio, the largest SO_2 emissions (2,398.4 kilotonnes per annum) for a single State.

The industrialized Ohio Valley area which includes Ohio and the surrounding States of Indiana-Illinois, Kentucky-Tennessee and Pennsylvania, has many large coal-fired power plants, 30 of which are included in the top 50 SO_2 emitting coal-fired power plants listed in Table XX. These six States together provided 47% of total eastern US SO_2 emissions.

Ohio also has the highest NO_x releases (1,038.4 kilotonnes per annum) for a single state. The Ohio Valley region emitted 37% of total eastern US NO_x emissions. Hydrocarbon emissions from the north-eastern States of Illinois-Indiana, Ohio, Pennsylvania, New York-New Jersey, constituted 36% of total eastern US HC emissions.

In eastern Canada, Ontario is the largest emitter of pollutants involved in acid rain formation. Ontario contributed 46% of total eastern Canadian SO_2 emissions, 47% of NO_x and 49% of HC. Sulfur dioxide releases in the Sudbury subregion constituted just over half (51%) of the Ontario SO_2 releases. Southwestern Ontario emitted one-third (36%) of the Ontario SO_2 and over three-quarters (78%) of the Ontario NO_x.

Quebec emitted 29% of eastern Canadian SO_2 and NO_x, along with a third of eastern Canadian HC. Sulfur dioxide emissions originated in the St. Lawrence Valley subregion (40%) and in Northern Quebec (48%). Nitrogen oxide emissions were almost entirely (89%) from the St. Lawrence Valley subregion.

Ontario Hydro generating stations, listed in Table XVIII, contributed less than a quarter (21.7%) of the Ontario SO_2 and less than a fifth (18.8%) of the Ontario NO_x emissions. In eastern Canada, Ontario Hydro contributed 10.0% and 8.9% of the SO_2 and NO_x emissions respectively. When compared to eastern US coal-fired generating plants in 1980, two Ontario Hydro plants were ranked in the top 50 in terms of total SO_2 emitted per year. Lambton Generating Station was ranked 22nd and Nanticoke TGS was in the 24th position. The Gavin Thermal Generating Station in Ohio was the largest emitter of SO_2 with 362.9 kilotonnes per year. This was more than twice the SO_2 emissions from Lambton Generating Station and four times the SO_2 emissions from Lakeview Generating Station.

The coal-fired power plants were also ranked according to SO_2 emission cleanliness in 1979 by using the estimated amount of SO_2 emitted per amount of energy produced. Lambton, Nanticoke and Lakeview Generating Stations ranked 30th, 36th and 37th, respectively, with an average cleanliness of about 3.4 lb SO_2/million BTU. This is more than three times as clean as the top ranking plant (10.86 lb SO_2/million BTU). These rankings were based on 1979 SO_2 figures which were higher than the 1980 data by 7% for Lambton and Nanticoke and by 22% for Lakeview.

In 1980, Ontario Hydro contributed approximately 1.7% of Eastern North American SO_2 emissions and about 0.8% of the NO_x emissions or 1.3% of the total acid gas emissions (SO_2 + NO_x). For all of

North America the estimated per cent contributions by Ontario Hydro were 1.4% and 0.5% for SO_2 and NO_x emissions, respectively or approximately 1% of the total acid gas emissions ($SO_2 + NO_x$). Ontario Hydro sulfur dioxide emissions were 1.6% of the US SO_2 emissions whereas Ontario Hydro nitrogen oxide emissions were 0.5% of the US NO_x emissions.

Seasonal variations, as determined from all available sources of information (MOI data/5/, and SURE area data/21/) show that SO_2 levels increased in the winter. However, the SURE area data did not show the minimum in summer SO_2 levels that was noted by the MOI Working Groups. Canadian data from the MOI Working Groups showed a maximum (28% of the annual emission) for summer NO_x emissions, whereas the SURE results did not indicate a significant seasonal variation in NO_x emissions. The SURE data did point to a large increase in winter HC emissions, from 24% of the annual emission in the fall to 33% in the winter. The SURE data were the only available literature source containing estimates of seasonal emissions for HC.

Historical emission data for the US from Tables I, II and III, varied by ±15%, from source to source. Emission estimates from United Technology and Science Inc, Table III/10/ were up to 15% higher in value than the emission estimates from the US Environmental Protection Agency (EPA)/9/, Table II and the US-Canada Memorandum of Intent (MOI)/5/, Table III.

In the 1980 data set, probable errors were available for State, Provincial and Canadian subregional NO_x and SO_2 emission estimates. Most eastern States had probable errors of between ±7% and ±12% for SO_2 emissions with an average probable error of ±10%. Nitrogen oxide emissions were slightly less accurate with probable errors of between ±8% and ±15% with an average probable error of ±11%. The national probable errors, for both NO_x and SO_2, were ±2%.

The average precision of the SO_2 emissions in the eastern Provinces was ±20% and for NO_x emissions the average precision was ±23%. Ontario and Quebec SO_2 emissions had precisions well below the average at values of ±9% and ±14%, respectively, whereas the accuracies for NO_x emissions were ±22% and ±26%, respectively. Emission estimates for the Canadian subregions showed average precisions of ±22% for SO_2 and ±28% for NO_x. The major Ontario SO_2 emission subregions of Sudbury and Southwestern Ontario had precisions of ±14% and ±18%, respectively. The St. Lawrence Valley and Northern Quebec SO_2 emissions were accurate to ±34% and ±14%, respectively. The major NO_x emission subregion, southwestern Ontario and the St. Lawrence Valley, Quebec had precisions of ±25% and ±31% respectively.

5.0 CONCLUSIONS

This report summarizes the available information on anthropogenic emissions of the pollutants, sulfur dioxide, nitrogen oxides and hydrocarbons, that are significant contributors to acid rain formation.

Historical emission trends indicated that US SO_2 and NO_x emissions peaked in the mid to late 1970's, whereas Canadian emissions and US HC emissions peaked about 1970. Sulfur dioxide emissions showed moderate changes (about 20-40%) from 1940 to the mid-1970's in the US and from 1955 to 1970 in Canada. Nitrogen oxide emissions showed dramatic increases of approximately 300% in the US from 1940 to the mid-1970's and roughly 500% in Canada from 1955 to 1974. US HC emissions increased about three-quarters from 1940 to 1970, and US and Canadian HC emissions both experienced a moderate decrease (about 25-35%) from 1970 to 1980.

US emission estimates, at best, had an accuracy of ±15% on a national, annual basis. The 1976 Canadian SO_2 inventory had an accuracy of ±30% at the 75% confidence level.

Historically, US SO_2 emissions have spread south and westward away from the northeastern States. This spreading has followed the historical trend in coal consumption.

Currently, the US emits almost 85% of North American SO_2 and about 90% of the NO_x and HC. One-third to one-half of these emissions originate in the industrialized Ohio Valley region of the Eastern US.

Ontario is responsible for just under one-half of the Canadian acid gas and hydrocarbon emissions. The Sudbury subregion emits approximately one-half of the SO_2 emissions for Ontario. The southwest subregion, including Toronto, emits about one-third of the Ontario SO_2 and just over three-quarters of the Ontario NO_x. Ontario Hydro emits nearly one-quarter of the Ontario SO_2 and almost one-fifth of the Ontario NO_x.

Seasonal variations in emissions indicated that the SO_2 emissions peak in the winter months. Canadian seasonal data pointed to a summertime peak of NO_x emissions which is not apparent from the Sulfate Regional Experiment(SURE) data. SURE data did show a wintertime peak in hydrocarbon emissions.

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TABLE I

HISTORICAL US ACID GAS AND HYDROCARBON EMISSIONS

Year	kilotonnes/year		
	SO_2	NO_x	HC
1940	19 500	6 000	17 000
1950	22 000	8 100	21 200
1960	21 400	10 500	28 000
1970	29 100	20 400	29 700
1971	27 900	21 300	29 300
1972	28 800	22 200	29 700
1973	29 700	22 900	29 800
1974	28 200	22 600	28 600
1975	25 700	22 200	26 200
1976	26 900	23 000	27 900
1978	27 000	23 300	N/A
1980	24 100	19 300	23 300

NO_x expressed as NO_2 equivalent.

N/A - not available.

Source: The 1940 to 1978 data are from the US-Canada Memorandum of Intent (MOI) on Transboundary Air Pollution, #3B - Final Report, June, 1982.

1980 data are from the unedited draft report by B.L. Niemann, The 1980 Data Set for Further Evaluation of Regional Air Quality/Acid Deposition Simulation Models, August 1982.

TABLE II

US ACID GAS AND HYDROCARBON EMISSIONS
FOR 1970 to 1977

Year	kilotonnes/year		
	SO_2	NO_x	HC
1970	29 800	19 600	29 500
1971	28 300	20 200	29 100
1972	29 600	21 600	29 600
1973	30 200	22 300	29 700
1974	28 400	21 700	28 600
1975	26 100	21 000	26 900
1976	27 200	22 800	28 700
1977	27 400	23 100	28 300

NO_x expressed as NO_2 equivalent

Source: US EPA, National Air Quality, Monitoring and Emissions Trend Report, 1977, Report No EPA-450/2-78-052, December, 1978.

TABLE III

US ACID GAS EMISSIONS FOR 1970 to 1975

Year	kilotonnes/year	
	SO_x	NO_x
1970	30 800	20 400
1971	29 100	21 100
1972	33 000	22 200
1973	32 000	23 100
1974	30 700	22 500
1975	29 600	21 800

NO_x expressed as NO_2 equivalent.

Source: United Technology and Science Inc, Acid Precipitation, Final Draft, December, 1979.

TABLE IV

HISTORICAL CANADIAN ACID GAS AND HYDROCARBON EMISSIONS

Year	kilo tonnes/year		
	SO_2	NO_x	HC
1955	4 390	300	N/A
1965	6 150	490	N/A
1970	6 540	1 230	2 790
1972	5 990	1 740	2 330
1974	5 600	1 890	2 270
1976	5 310	1 860	2 650
1980	4 770	1 830	1 970

NO_x expressed as NO_2 equivalent. N/A - not available.

Source: The 1955 and 1965 data are from the US-Canada Memorandum of Intent (MOI) on Transboundary Air Pollution, Interim Report, February, 1981. The 1970 to 1976 data are from Environment Canada, Air Pollution Control Directorate, A Nationwide Inventory of Air Pollution Emissions (1970) and (1972), Reports No EPS 3-AP-73-2 and EPS-3-AP-77-2.
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The 1980 data are from an unedited draft report by B.L. Niemann, The 1980 Data Set for Further Evaluation of Regional Air Quality/Acid Deposition Simulation Models, August, 1982.

TABLE V

HISTORICAL EASTERN CANADIAN* ACID GAS AND HYDROCARBON EMISSIONS

Year	kilotonnes/year					
	SO_2	(% of Canadian Emission)	NO_x	(% of Canadian Emission)	HC	(% of Canadian Emission)
1955	4 200	(95.7)	240	(80.0)	N/A	
1965	5 400	(86.2)	370	(75.5)	N/A	
1970	5 660	(86.5)	820	(66.7)	1 970	(50.8)
1972	4 810	(80.3)	1 130	(64.9)	1 460	(62.7)
1974	4 540	(81.1)	1 140	(60.3)	1 690	(74.4)
1976	4 500	(84.7)	1 170	(62.9)	1 700	(64.2)
1980	3 980	(83.4)	1 130	(62.3)	1 270	(64.5)

* - Eastern Canada includes Manitoba
N/A - not available
NO_x expressed as NO_2 equivalent

Source: As listed for Table IV.

TABLE VI

ONTARIO ACID GAS AND HYDROCARBON EMISSIONS IN THE 1970's

Year	kilotonnes/year		
	SO_2	NO_x	HC
1970	3 400	420	920
1972	2 520	540	620
1974	2 120	610	830
1976	2 320	550	800
1980	1 830	540	620

NO_x expressed as NO_2 equivalent.

Source: As listed for Table IV.

TABLE VII

HISTORICAL US NO_x TO HC RATIO

Year	$\frac{NO_x}{HC}$ [1]	$\frac{NO_x}{HC}$ [2]
1940	0.353	-
1950	0.382	-
1960	0.375	-
1970	0.687	0.664
1971	0.727	0.694
1972	0.747	0.730
1973	0.768	0.751
1974	0.790	0.759
1975	0.847	0.781
1976	0.824	0.794
1977	-	0.816
1980	0.828	0.828

[1] Ratios calculated from MOI data in Table I/5,7/.

[2] Ratios calculated from EPA data in Table II/9/. NO_x expressed as NO_2 equivalent.

TABLE VIII

CANADIAN NO_x TO HC RATIO FOR THE 1970's

Year	Canada	Eastern Canada	Ontario
1970	0.441	0.416	0.457
1972	0.747	0.774	0.871
1974	0.833	0.675	0.735
1976	0.702	0.688	0.688
1980	0.929	0.890	0.871

NO_x expressed as NO_2 equivalent.

Ratios calculated from the data in Tables IV, V and VI.

TABLE IX

HISTORICAL US TRENDS IN SO_2 EMISSIONS

State	kilotons**						
	1950	1955	1960	1965	1970	1975	1978
EPA - REGION I							
Conn.	130.3	139.1	241.6	457.6	317.3	191.0	112
Maine	37.8	45.6	70.2	97.0	82.0	67.8	66
Mass.	906.4	956.7	374.6	443.2	584.4	362.2	402.2
New Hamp.	73.3	89.7	29.1	41.2	95.9	75.4	67.8
Rhode Island	67.7	80.2	87.3	41.2	60.1	24.3	19.7
TOTAL	1215.5	1311.3	802.8	1080.2	1139.1	720.7	667.7
EPA - REGION II							
New York	847.0	1126.0	1427.4	1645.4	1455.0	1079.0	1041.1
New Jersey	*1308.8	*1486.2	482.6	623.4	590.2	341.0	323.7
TOTAL	*2155.8	*2612.20	1910.00	2268.8	2045.2	1420.0	1364.8
EPA - REGION III							
Delaware	105.4	136.0	196.1	217.8	223.4	193.6	188.2
D.C.	32.4	31.0	38.5	47.9	78.0	27.1	17.6
Maryland	398.9	515.5	518.2	588.1	467.7	322.3	357.3
Penn.	* 970.2	2138.4	2362.2	2546.8	2245.7	2130.8	1900.0
Virginia	157.2	277.4	171.4	188.1	475.2	381.0	359.9
West Va.	243.5	617.8	529.7	776.8	979.7	1220.0	1049.5
TOTAL	*1907.6	3716.1	3816.1	4365.5	4469.7	4274.8	3872.5
EPA - REGION IV							
Alabama	139.5	522.7	613.5	892.3	979.1	986.5	762.1
Florida	225.5	350.5	341.1	501.6	862.3	827.9	685.9
Georgia	119.9	163.6	198.2	303.0	410.4	571.4	707.0
Mississippi	46.9	43.3	41.1	44.6	79.4	193.0	264.3
Kentucky	113.1	404.8	631.1	914.0	1280.9	1466.8	1330.0
North Carolina	306.1	347.4	232.4	294.4	533.2	500.5	562.3
South Carolina	44.5	84.3	115.9	121.7	185.4	202.3	288.6
Tennessee	97.3	369.2	731.2	771.5	988.1	1141.9	1162.8
TOTAL	1092.8	2285.8	2904.5	3843.1	5318.8	5890.3	5763.0

*Questionable Data

Northeastern States - Region I, II
Mid-Atlantic States - Region III
Southeastern States - Region IV

**Note: 1 ton = 0.9072 tonne

Source: US-Canada Memorandum of Intent on Transboundary Air Pollution, Interim Report, February, 1981.

TABLE X

1980 EMISSIONS FOR NORTH AMERICA

kilotonnes/year

	North America	US	(% of North America)	Eastern US	(% of US)	Canada	(% of North America)	Eastern Canada	(% of Canada)
SO_2	28 900	24 100	(83.4%)	19 800	(82.2%)	4 770	(16.5%)	3 980	(83.4%)
NO_x	21 100	19 300	(91.3%)	12 100	(63.6%)	1 830	(9.7%)	1 130	(61.8%)
HC	25 300	23 300	(92.2%)	15 300	(64.5%)	1 970	(7.8%)	1 270	(64.3%)

Eastern US includes the States bordering on the Mississippi River.

Eastern Canada includes Manitoba.

NO_x expressed as NO_2 equivalent.

Source: Unedited draft report by B.L. Niemann, The 1980 Data Set for Further Evaluation of Regional Air Quality/Acid Deposition Simulation Models, August 1982.

Personal Communication from F. Vena, Environment Canada, Hull, Quebec, November 10, 1982.

TABLE XI

1980 EMISSIONS FOR EASTERN US BY STATES AND REGIONS

Region	kilotonnes/year		
	SO_2	NO_x	HC
Michigan	822.6	625.9	920
Wisconsin	544.1	381.4	437
Ohio	2 398.4	1 038.4	1 057
Pennsylvania	1 812.4	941.2	1 124
New York - New Jersey	1 117.3	984.8	1 705
Illinois - Indiana	3 154.8	1 613.3	1 554
Kentucky - Tennessee	1 971.1	951.2	840
Northeast States	567.8	511.6	1 112
Central East States	2 584.0	1 791.8	2 284
Southeast States	2 713.7	1 703.7	1 919
Middle States	2 085.9	1 724.0	2 119
Total Eastern US	19 772.1	12 267.3	15 071

NO_x expressed as NO_2 equivalent.

Northeast States: Vermont, New Hampshire, Maine, Massachusetts, Connecticut, Rhode Island.

Central East States: West Virginia, Virginia, North and South Carolina, Maryland, Delaware, District of Columbia.

Southeast States: Mississippi, Alabama, Georgia, Florida.

Middle States: Louisiana, Arkansas, Missouri, Iowa, Minnesota.

Source: Unedited draft report by B.L. Niemann, The 1980 Data Set for Further Evaluation of Regional Air Quality/Acid Deposition Simulation Models, August, 1982.

TABLE XII

EASTERN CANADIAN EMISSIONS BY PROVINCES

	kilotonnes/year					
	SO_x	(% Eastern Canada)	NO_x	(% Eastern Canada)	HC	(% Eastern Canada)
Maritimes	500.9	(12.6%)	185.4	(16.4%)	153.4	(12.1%)
Quebec	1 157.9	(29.1%)	331.4	(29.3%)	414.9	(32.7%)
Ontario	1 830.6	(46.0%)	536.5	(47.4%)	620.3	(48.9%)
Manitoba	489.9	(12.3%)	78.2	(6.9%)	80.7	(6.3%)

NO_x expressed as NO_2 equivalent.

Source: Unedited draft report by B.L. Niemann, The 1980 Data Set for Further Evaluation of Regional Air Quality/Acid Deposition Simulation Models, August, 1982.

Personal Communication from F. Vena, Environment Canada, Hull, Quebec, November 10, 1982.

TABLE XIII

EASTERN CANADIAN EMISSIONS BY PROVINCE AND SUBREGIONS

Region No	Province(s) and Subregion	kilotonnes/year			
		SO_2	(% of Manitoba Emissions)	NO_x	(% of Manitoba Emissions)
10	Northern Manitoba	464.1	(94.7)	5.7	(7.3)
11	Southern Manitoba	25.8	(5.3)	72.5	(92.7)
			(% of Ontario Emissions)		(% of Ontario Emissions)
12	Northwestern Ontario	24.8	(1.4)	18.5	(3.4)
13	Northeastern Ontario	180.2	(9.8)	18.5	(3.4)
14	Sudbury, Ontario	939.8	(51.3)	10.0	(1.9)
15	Southwestern Ontario	650.7	(35.6)	417.6	(77.9)
16	Southeastern, Ontario	35.0	(1.9)	71.9	(13.4)
			(% of Quebec Emissions)		(% of Quebec Emissions)
17	The St. Lawrence Valley, Quebec	467.2	(40.4)	295.1	(89.1)
18	Northern Quebec	559.8	(48.3)	12.9	(3.9)
19	Gaspe Bay, Quebec	130.9	(11.3)	23.3	(7.0)
			(% of Maritime Emissions)		(% of Maritime Emissions)
20	New Brunswick	215.4	(43.0)	59.2	(31.9)
21	PEI and Nova Scotia	224.6	(44.8)	95.0	(51.3)
22	Newfoundland with Labrador	60.9	(12.2)	31.1	(16.8)

NO_x expressed as NO_2 equivalent.

Source: Unedited draft report by B.L. Niemann, The 1980 Data Set for Further Evaluation of Region Air Quality/Acid Deposition Simulation Models, August, 1982.

Personal Communication from F. Vena, Environment Canada, Hull, Quebec, November 10, 1982.

TABLE XIV

PROBABLE ERROR IN EASTERN US ESTIMATED EMISSIONS

State	Total SO_2 kilotonnes/ year	Probable Error (±%)	Total No_x kilotonnes/yr	Probable Error (±%)
Alabama	707.0	8.3	408.6	8.2
Arkansas	92.0	14.2	197.2	9.5
Connecticut	65.3	10.3	121.6	10.2
Delaware	99.0	8.7	47.1	22.9
District of Columbia	13.4	14.0	19.9	15.2
Florida	993.2	18.4	588.0	12.3
Georgia	752.3	9.1	448.3	8.8
Illinois	1 336.1	7.5	912.0	11.1
Indiana	1 818.7	7.2	701.3	14.1
Iowa	299.3	10.3	290.9	13.9
Kentucky	994.6	8.3	482.0	12.2
Louisiana	276.2	10.2	842.2	8.6
Maine	86.0	10.5	53.9	9.6
Maryland	306.6	7.9	225.1	8.3
Massachusetts	312.5	6.6	230.0	10.7
Michigan	822.6	11.7	625.9	8.7
Minnesota	238.8	11.3	338.8	12.1
Mississippi	261.2	9.2	258.8	8.2
Missouri	1 179.6	8.5	514.9	13.9
New Hampshire	84.1	8.5	50.6	13.9
New Jersey	253.3	10.8	368.3	10.6
New York	864.0	5.9	616.5	8.4
North Carolina	546.8	10.2	486.5	8.6
Ohio	2 398.4	11.1	1 038.4	11.3
Pennsylvania	1 812.4	7.7	941.2	9.2
Rhode Island	13.8	11.1	33.1	11.9
South Carolina	301.7	8.4	236.1	15.8
Tennessee	976.5	8.0	469.2	8.1
Vermont	6.1	15.1	22.4	12.7
Virginia	327.1	6.8	367.1	10.6
West Virginia	989.4	8.6	410.3	12.0
Wisconsin	544.1	9.6	381.4	9.4

NO_x expressed as NO_2 equivalent.

Source: Personal Communication from C. Mann, US-EPA, North Carolina, October 14, 1982.

TABLE XV

PRECISION OF CANADIAN EMISSION ESTIMATES

Provincial SO_2 Emissions

Province	Emissions kilotonnes/yr	Precision (±%)
Newfoundland	60.925	25.7
Prince Edward Island	5.794	44.1
Nova Scotia	218.781	14.5
New Brunswick	215.428	14.4
Quebec	1 157.916	14.5
Ontario	1 830.600	9.4
Manitoba	489.918	10.3
Provincial NO_X Emissions		
Newfoundland	31.148	28.8
Prince Edward Island	6.849	24.9
Nova Scotia	88.129	18.0
New Brunswick	59.247	21.6
Quebec	331.358	25.9
Ontario	536.469	21.7
Manitoba	78.157	22.2

NO_X expressed as NO_2 equivalent.

Source: Unedited draft report by B.L. Niemann, The 1980 Data Set for Further Evaluation of Regional Air Quality/Acid Deposition Simulation Models, August, 1982.

Personal Communication from F. Vena, Environment Canada, Hull, Quebec, November 10, 1982.

TABLE XVI

PRECISION OF CANADIAN SO_2 EMISSION ESTIMATES AT THE SUBREGION LEVEL

Subregion No	Emissions kilotonnes/year	Precision (±%)
10	464.115	10.6
11	25.803	46.8
12	24.842	26.8
13	180.200	17.9
14	939.838	14.1
15	650.760	17.9
16	35.005	37.6
17	467.234	33.7
18	559.762	14.4
19	130.920	17.8
20	215.428	14.4
21	224.575	14.5
22	60.925	25.7

Source: Unedited draft report by B.L. Niemann, The 1980 Data Set for Further Evaluation of Regional Air Quality/Acid Deposition Simulation Models, August, 1982.

Personal Communication from F. Vena, Environment Canada, Hull, Quebec, November 10, 1982.

TABLE XVII

PRECISION OF CANADIAN NO_x EMISSION ESTIMATES AT THE SUBREGION LEVEL

Subregion No	Emissions kilotonnes/year	Precision (±%)
10	5.658	26.9
11	72.499	26.9
12	18.476	28.2
13	18.534	29.4
14	10.041	33.9
15	417.566	24.5
16	71.852	30.4
17	295.139	30.6
18	12.939	32.1
19	23.280	37.1
20	59.247	21.6
21	94.978	17.8
22	31.148	28.8

NO_x expressed as NO_2 equivalent.

Source: Unedited draft report by B.L. Niemann, The 1980 Data Set for Further Evaluation of Regional Air Quality/Acid Deposition Simulation Models, August, 1982.

TABLE XVIII

ONTARIO HYDRO 1980 EMISSIONS

Station	kilotonnes/year	
	SO_2	NO_x
J. Clark Keith (Windsor)	0.850	0.215
Thunder Bay	9.730	1.549
R.L. Hearn (Downtown Toronto)	16.300	4.661
Lakeview (West of Toronto)	75.100	19.778
Lambton (Sarnia)	150.000	18.858
Nanticoke	144.000	55.655
Lennox (West of Kingston)	0.324	0.101
Total	396.304	100.817

NO_x expressed as NO_2 equivalent.

Source: Ontario Hydro Thermal Generation Division Report CTS-07120-1 "Estimates of Atmospheric Emissions from Ontario Hydro Fossil-Fuel-Fired Thermal Generating Stations During 1980".

TABLE XIX

RELATIVE CONTRIBUTION BY ONTARIO HYDRO TO PROVINCIAL, NATIONAL AND NORTH AMERICAN EMISSIONS

	kilotonnes SO_2	% Relative Contribution by Ontario Hydro
Ontario	1 830.6	21.7
Eastern Canada	3 979.4	10.0
Canada	4 769.4	8.3
US	24 131.5	1.6
Eastern North America	23 751.5	1.7
North America	28 900.9	1.4
	kilotonnes NO_x	
Ontario	536.5	18.8
Eastern Canada	1 131.5	8.9
Canada	1 832.1	5.5
US	19 293.1	0.5
Eastern North America	13 398.8	0.8
North America	21 125.2	0.5

NO_x expressed as NO_2.

Source: Unedited draft report by B.L. Niemann, The 1980 Data Set for Further Evaluation of Regional Air Quality/Acid Deposition Models, August, 1982.

Ontario Hydro Thermal Generation Division Report CTS-07120-1 "Estimates of Atmospheric Emissions from Ontario Hydro Fossil-Fuel-Fired Thermal Generating Stations During 1980."

TABLE XX

TOP 50 COAL-FIRED POWER PLANTS IN EASTERN NORTH AMERICA RANKED ACCORDING TO TOTAL SO_2 EMISSIONS IN 1980*

RANK	PLANT	STATE	COUNTRY	ESTIMATED SO_2 EMISSION THOUSANDS OF METRIC TONS/YEAR
1	GAVIN	OHIO	USA	362.9
2	CUMBERLAND	TENNESSEE	USA	325.2
3	PARADISE	KENTUCKY	USA	314.5
4	GIBSON STATION	INDIANA	USA	275.3
5	CLIFTY CREEK	INDIANA	USA	261.4
6	BALDWIN	ILLINOIS	USA	235.2
7	BOWEN	GEORGIA	USA	227.6
8	MUSKINGUM	OHIO	USA	221.9
9	LABADIE	MISSOURI	USA	213.2
10	MONROE	MICHIGAN	USA	212.3
11	HARRISON	WEST VIRGINIA	USA	195.9
12	WANSLEY	GEORGIA	USA	191.9
13	CONESVILLE	OHIO	USA	189.0
14	KINCAID	ILLINOIS	USA	186.4
15	CONEMAUGH	PENNSYLVANIA	USA	186.1
16	KYGER CREEK	OHIO	USA	183.5
17	MADRID	MISSOURI	USA	180.9
18	HOMER CITY	PENNSYLVANIA	USA	167.3
19	HATFIELD	PENNSYLVANIA	USA	155.4
20	MITCHELL	WEST VIRGINIA	USA	154.8
21	GASTON	ALABAMA	USA	151.7
22	LAMBTON	ONTARIO	CANADA	150.0
23	MONTROSE	MISSOURI	USA	146.5
24	NANTICOKE	ONTARIO	CANADA	144.0
25	EASTLAKE	OHIO	USA	140.1
26	BIG BEND	FLORIDA	USA	139.6
27	COFFEEN	ILLINOIS	USA	139.2
28	KAMMER	WEST VIRGINIA	USA	135.6
29	KEYSTONE	PENNSYLVANIA	USA	129.1
30	BRUNNER ISLAND	PENNSYLVANIA	USA	126.1
31	GALLATIN	TENNESSEE	USA	124.3
32	SAMMIS	OHIO	USA	124.3
33	HILL	MISSOURI	USA	123.6
34	JOHNSONVILLE	TENNESSEE	USA	122.8
35	COLBERT	ALABAMA	USA	114.8
36	CARDINAL	OHIO	USA	112.5
37	CAYUGA	INDIANA	USA	104.7
38	STUART	OHIO	USA	103.3
39	MONTOUR	PENNSYLVANIA	USA	99.4
40	YATES	GEORGIA	USA	97.9
41	AMOS	WEST VIRGINIA	USA	95.4
42	PETERSBURG	INDIANA	USA	94.7
43	SHAWNEE	KENTUCKY	USA	94.0
44	JOPPA	ILLINOIS	USA	90.4
45	TANNERS CREEK	INDIANA	USA	90.1
46	FT. MARTIN	WEST VIRGINIA	USA	86.8
47	SIOUX	MISSOURI	USA	84.6
48	MILL CREEK	KENTUCKY	USA	84.4
49	MORGANTOWN	MARYLAND	USA	83.7
50	MT. STORM	WEST VIRGINIA	USA	83.3

*POWER PLANTS WERE CONSIDERED FROM ONTARIO AND 32 EASTERN U.S. STATES. THE STATISTICS ARE FROM ONTARIO HYDRO AND THE U.S. DEPARTMENT OF ENERGY; THE ANALYSIS WAS PERFORMED BY THE ONTARIO MINISTRY OF ENVIRONMENT, AIR RESOURCES BRANCH.

Source: Ontario Ministry of the Environment, "Case Against the Rain", October, 1980: Revision - Summer, 1982.

TABLE XXI

TOP 50 COAL-FIRED POWER PLANTS RANKED ACCORDING TO SO_2 EMISSION

"CLEANLINESS" IN 1979

RANK	PLANT	STATE	COUNTRY	ESTIMATED LBS. SO_2/ MILLION BTU	MAXIMUM ACCORDING TO STATE REGULATION (LBS. SO_2/ MILLION BTU)
1	MONTROSE	MISSOURI	U.S.A.	10.86	16.00
2	MUSKINGUM	OHIO	U.S.A.	8.72	6.48
3	THOMAS HILL	MISSOURI	U.S.A.	7.85	16.00
4	KAMMER	WEST VIRGINIA	U.S.A.	7.24	3.20
5	PARADISE	KENTUCKY	U.S.A.	7.22	5.20
6	KINCAID	ILLINOIS	U.S.A.	6.94	6.00
7	CLIFTY CREEK	INDIANA	U.S.A.	6.85	1.20
8	COFFEEN	ILLINOIS	U.S.A.	6.78	6.00
9	KYGER CREEK	OHIO	U.S.A.	6.50	8.20
10	NEW MADRID	MISSOURI	U.S.A.	5.75	16.00
11	CUMBERLAND	TENNESSEE	U.S.A.	5.71	5.00
12	MITCHELL	WEST VIRGINIA	U.S.A.	5.39	3.12
13	JOHNSONVILLE	TENNESSEE	U.S.A.	5.15	1.20
14	EASTLAKE	OHIO	U.S.A.	5.14	1.43
15	CONESVILLE	OHIO	U.S.A.	5.11	5.66
16	GIBSON	INDIANA	U.S.A.	5.09	16.00
17	BALDWIN	ILLINOIS	U.S.A.	5.08	1.80
18	GAVIN	OHIO	U.S.A.	4.92	9.50
19	CAYUGA	INDIANA	U.S.A.	4.41	16.00
20	GALLATIN	TENNESSEE	U.S.A.	4.38	5.00
21	BIG BEND	FLORIDA	U.S.A.	4.26	1.50
22	AVON LAKE	OHIO	U.S.A.	4.07	1.15
23	BECKJORD	OHIO	U.S.A.	4.01	2.02
24	LABADIE	MISSOURI	U.S.A.	3.99	16.00
25	HARRISON	WEST VIRGINIA	U.S.A.	3.93	4.11
26	HATFIELDS	PENNSYLVANIA	U.S.A.	3.86	4.00
27	MONROE	MICHIGAN	U.S.A.	3.77	5.60
28	CONEMAUGH	PENNSYLVANIA	U.S.A.	3.77	4.00
29	SAMMIS	OHIO	U.S.A.	3.70	2.91
30	LAMBTON	ONTARIO	CANADA	3.55	-
31	PETERSBURGH	INDIANA	U.S.A.	3.44	16.00
32	JOPPA STEAM	ILLINOIS	U.S.A.	3.41	6.00
33	BRUNNER ISL.	PENNSYLVANIA	U.S.A.	3.38	4.00
34	SHAWNEE	KENTUCKY	U.S.A.	3.37	1.20
35	MIAMI FORT	OHIO	U.S.A.	3.34	3.30
36	LAKEVIEW	ONTARIO	CANADA	3.33	-
37	NANTICOKE	ONTARIO	CANADA	3.29	-
38	WANSLEY	GEORGIA	U.S.A.	3.25	N/A
39	BOWEN	GEORGIA	U.S.A.	3.10	N/A
40	MT STORM	WEST VIRGINIA	U.S.A.	3.09	2.90

TABLE XXI (cont'd)

RANK	PLANT	STATE	COUNTRY	ESTIMATED LBS. SO_2/ MILLION BTU	MAXIMUM ACCORDING TO STATE REGULATION (LBS. SO_2/ MILLION BTU)
41	HOMER CITY	PENNSYLVANIA	U.S.A.	3.09	4.00
42	CARDINAL	OHIO	U.S.A.	3.00	4.76
43	GASTON EC	ALABAMA	U.S.A.	2.95	1.20
44	YATES	GEORGIA	U.S.A.	2.93	N/A
45	WIDOWS CREEK	ALABAMA	U.S.A.	2.88	1.20
46	FORT MARTIN	WEST VIRGINIA	U.S.A.	2.83	3.20
47	KEYSTONE	PENNSYLVANIA	U.S.A.	2.82	4.00
48	MONTOUR	PENNSYLVANIA	U.S.A.	2.51	4.00
49	STUART J.M.	OHIO	U.S.A.	2.04	3.16
50	AMOS	WEST VIRGINIA	U.S.A.	1.30	2.01

Power plants were considered from Ontario and 32 Eastern US States. The statistics are from Ontario Hydro and the US Department of Energy; the analysis was performed by the Ontario Ministry of Environment, Air Resources Branch.

Source: Ontario Ministry of Environment, A Submission to the US-EPA Opposing Relaxation of SO_2 Emission Limits in State Implementation Plans and Urging Enforcement, Expanded, March 29, 1981.

TABLE XXII

SEASONAL VARIATION IN CANADIAN SO_2 AND NO_x EMISSIONS

Months	% of annual emissions	
	SO_2	NO_x
December - February	29	25
March - May	24	23
June - August	22	28
September- November	25	24

NO_x expressed as NO_2 equivalent.

Source: US-Canada Memorandum of Intent on Transboundary Air Pollution, Interim Report, February, 1981.

TABLE XXIII

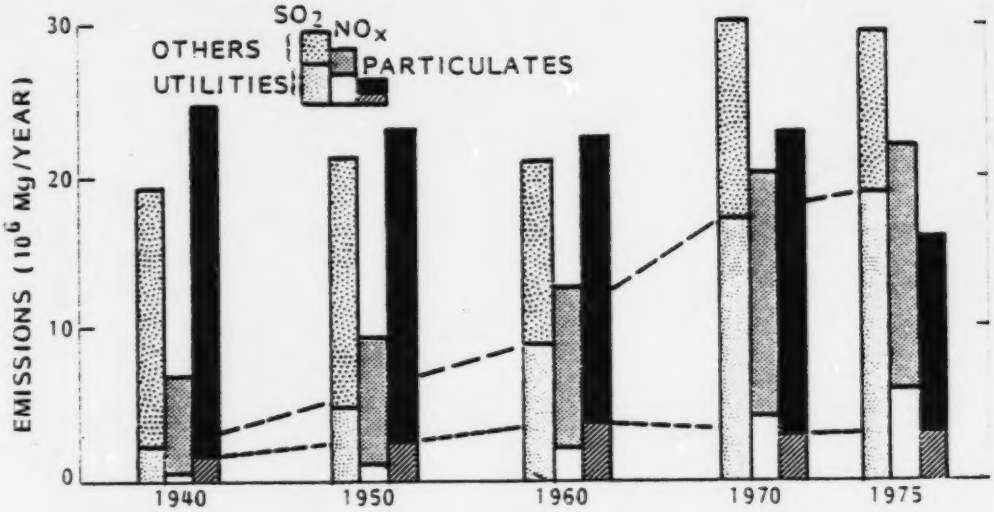
SEASONAL EMISSIONS FOR THE SURE REGION

	Winter		Spring		Summer		Fall	
	kilotonnes per day	(% of annual emission)	kilotonnes per day	(% of annual emission)	kilotonnes per day	(% of annual emission)	kilotonnes per day	(% of annual emission)
SO_2	89.8	(27)	78.0	(24)	78.7	(24)	80.3	(25)
NO_x	33.2	(26)	31.6	(24)	32.7	(25)	32.1	(25)
HC*	36.7	(33)	25.7	(23)	21.8	(20)	26.9	(24)

*Moderate reactivity.

NO_x expressed as NO_2 equivalent.

Source: Emission Inventory for the SURE Region, EPRI Report No EA-1913, Final Report, April, 1981, prepared by GCA Corporation, Bedford, Mass.



SOURCE: FLEMING, R.A. AND GILLIES, D.K.A, ACID PRECIPITATION: AN EMISSIONS PERSPECTIVE, ONTARIO HYDRO REPORT NO. CTS-07165-1, NOVEMBER 23, 1979

FIGURE 1

HISTORICAL TRENDS IN USA EMISSIONS

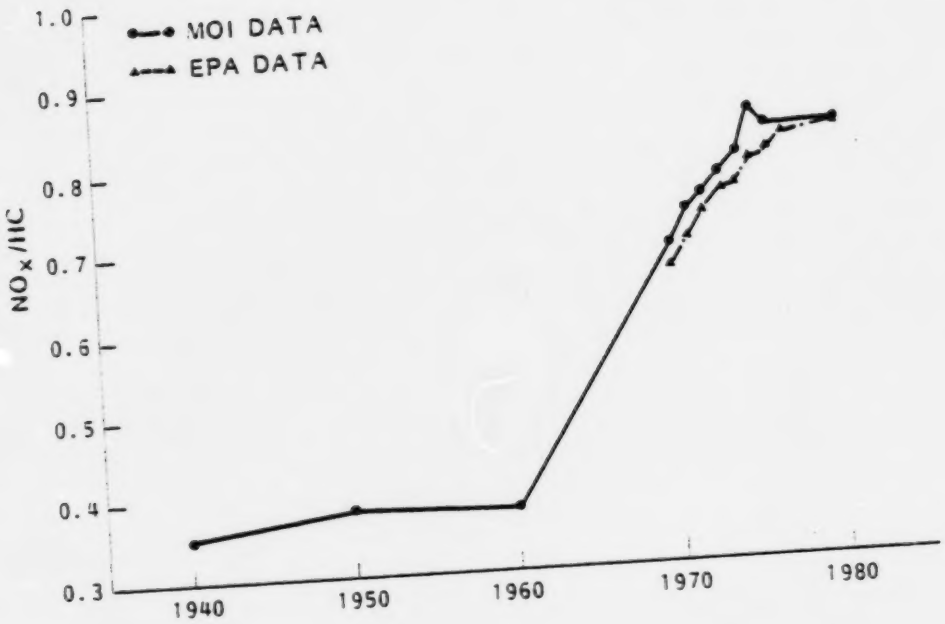


FIGURE 2
HISTORICAL TRENDS IN US NO_x TO HC RATIO

FIGURE 3

US HISTORICAL SULFUR EMISSION DENSITY DUE TO COAL COMBUSTION

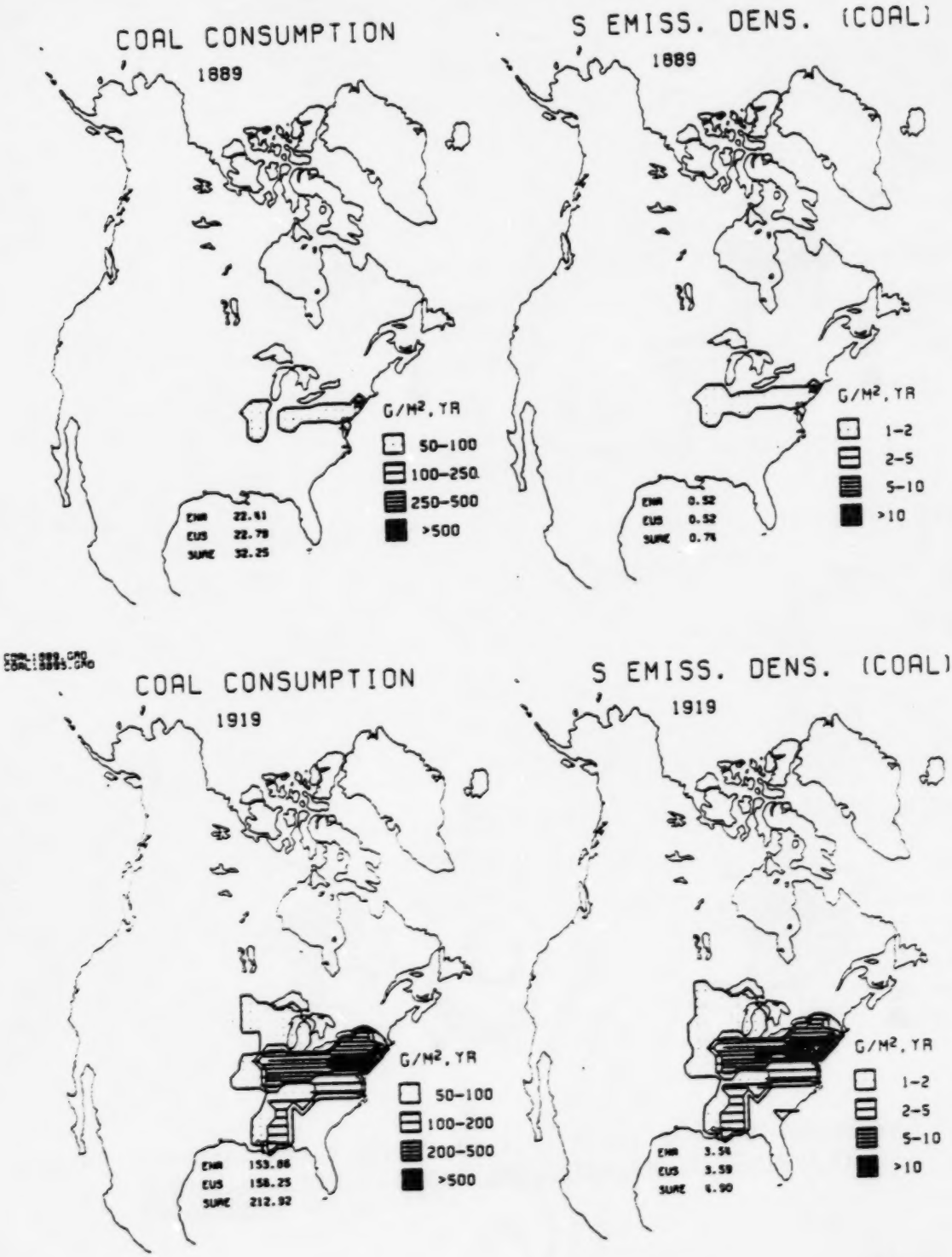
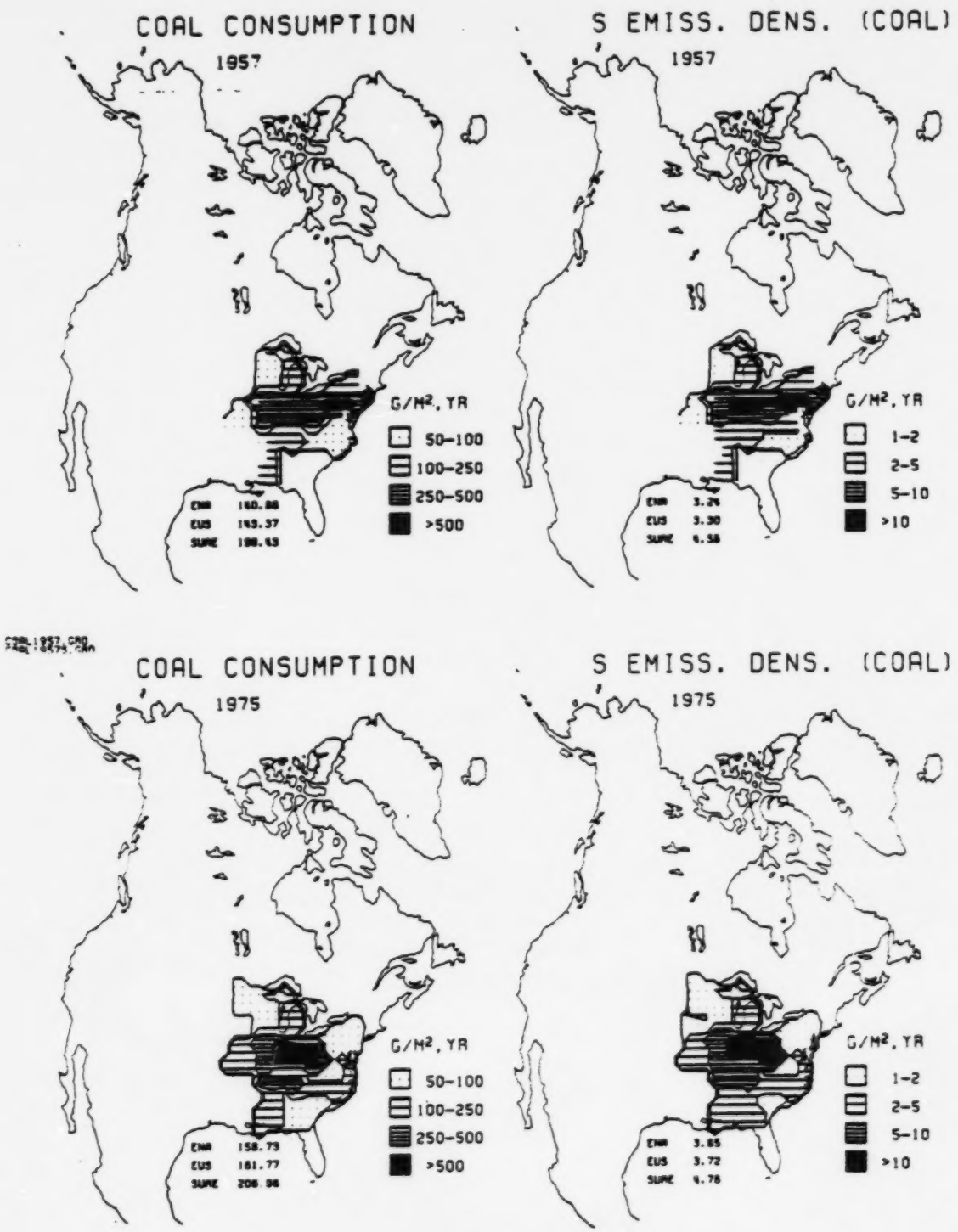


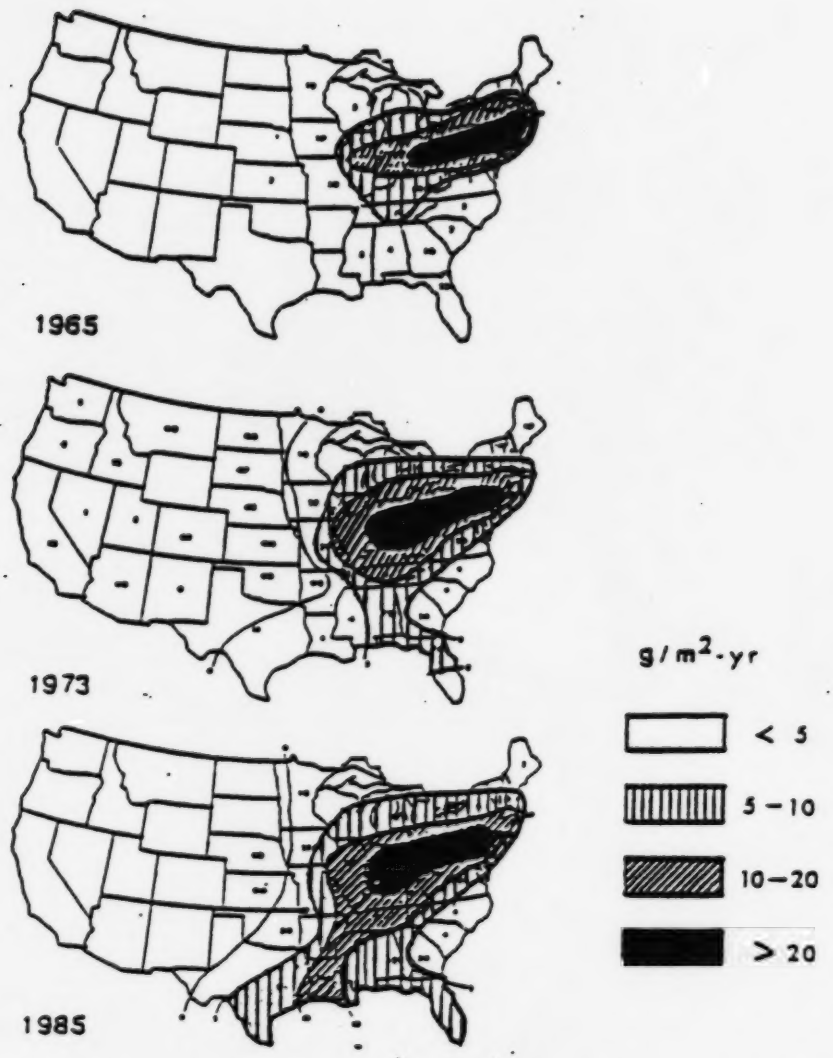
FIGURE 3 (cont'd)



Source: Unedited Draft Report by R.B. Husar and J.M. Holloway, Historical and Geographical Patterns of SO_x and NO_x Emissions, April, 1982

FIGURE 4

TRENDS IN US SULFUR EMISSION DENSITY



Source: Unedited Draft Report by R.B. Husar and J.M. Holloway, Historical and Geographical Patterns of SO_x and NO_x Emissions, April, 1982.

EPA REGION I, II } NORTHEASTERN STATES
EPA REGION III - MID ATLANTIC STATES
EPA REGION IV - SOUTHERN STATES

FIGURE 5

THE EPA REGIONS IN EASTERN US

159932 RD

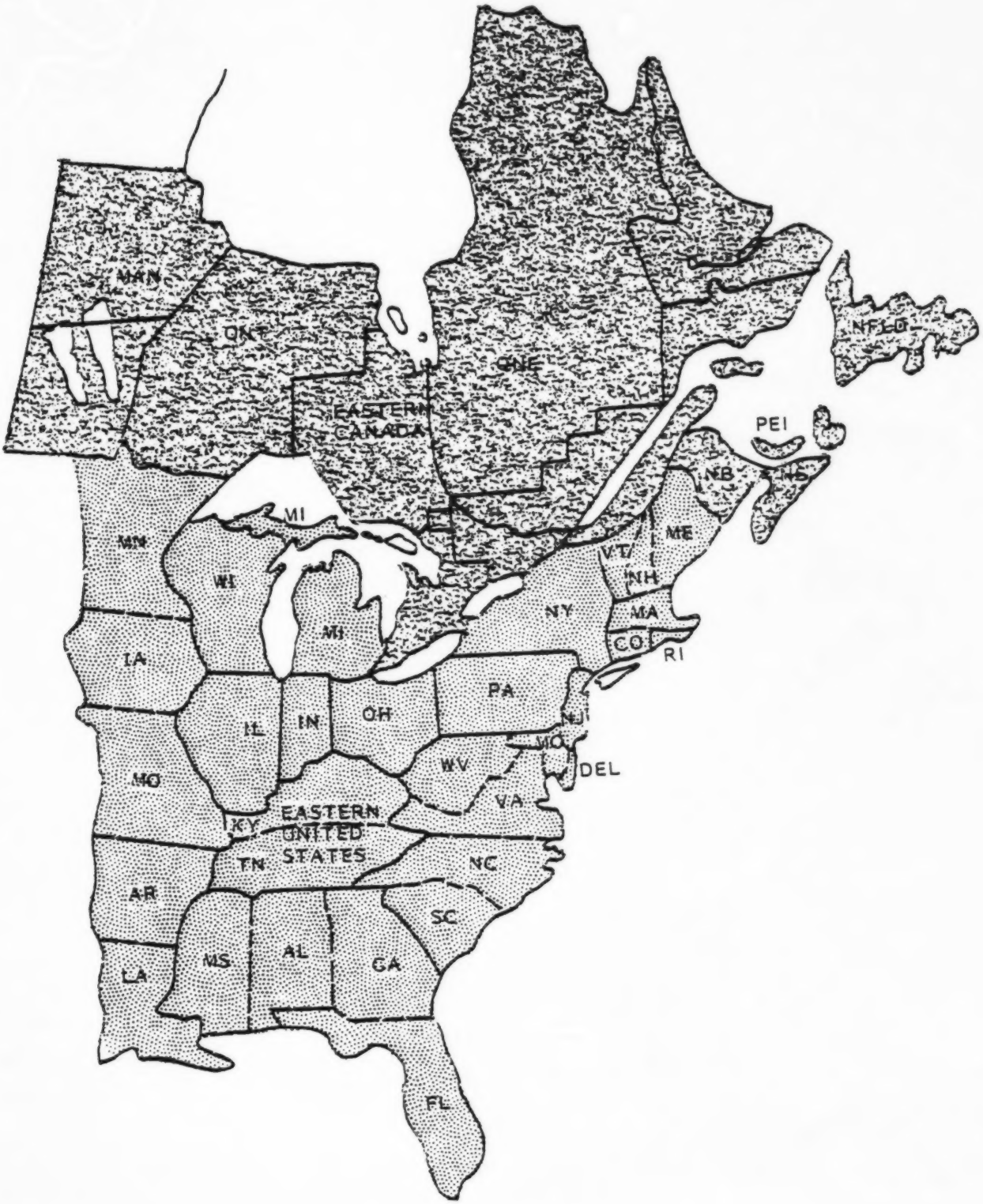


FIGURE 6
EASTERN NORTH AMERICA

159933 RD

FIGURE 7

EASTERN US STATES AND REGIONS

SUBREGIONS ARE NUMBERED ACCORDING TO TABLE 13

FIGURE 8
EASTERN CANADIAN SUBREGIONS

159935 P.D

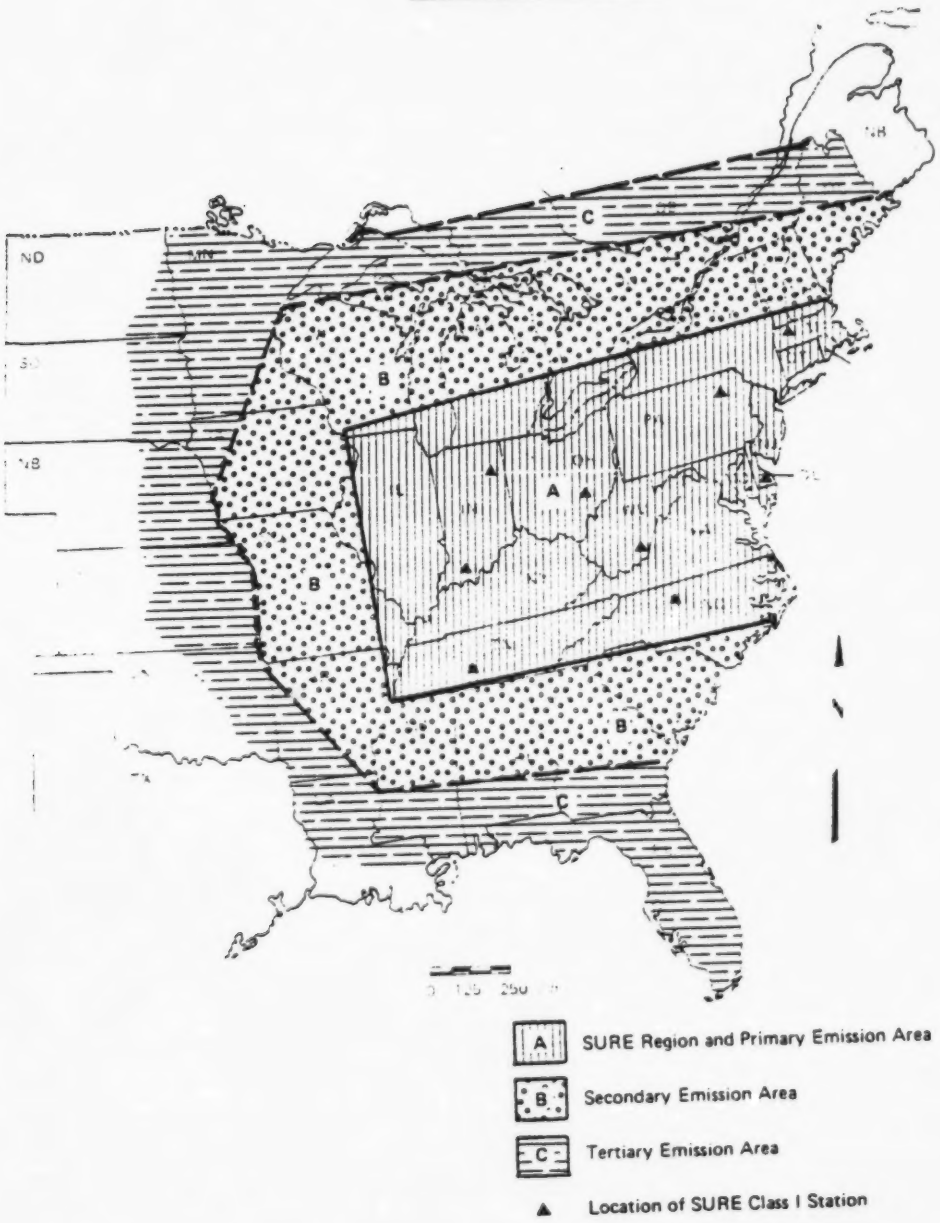
FIGURE 9

1980 SO_2 EMISSIONS FOR EASTERN NORTH AMERICA
IN kilotonnes / year

159936 RD

FIGURE 10

THE SURE REGION



Source: Implementation and Coordination of the Sulfate Regional Experiment (SURE) and Related Research Programs, EPRI Report No EA-1066, Interim Report, June, 1979.

POOR

QUALITY

ORIGINAL